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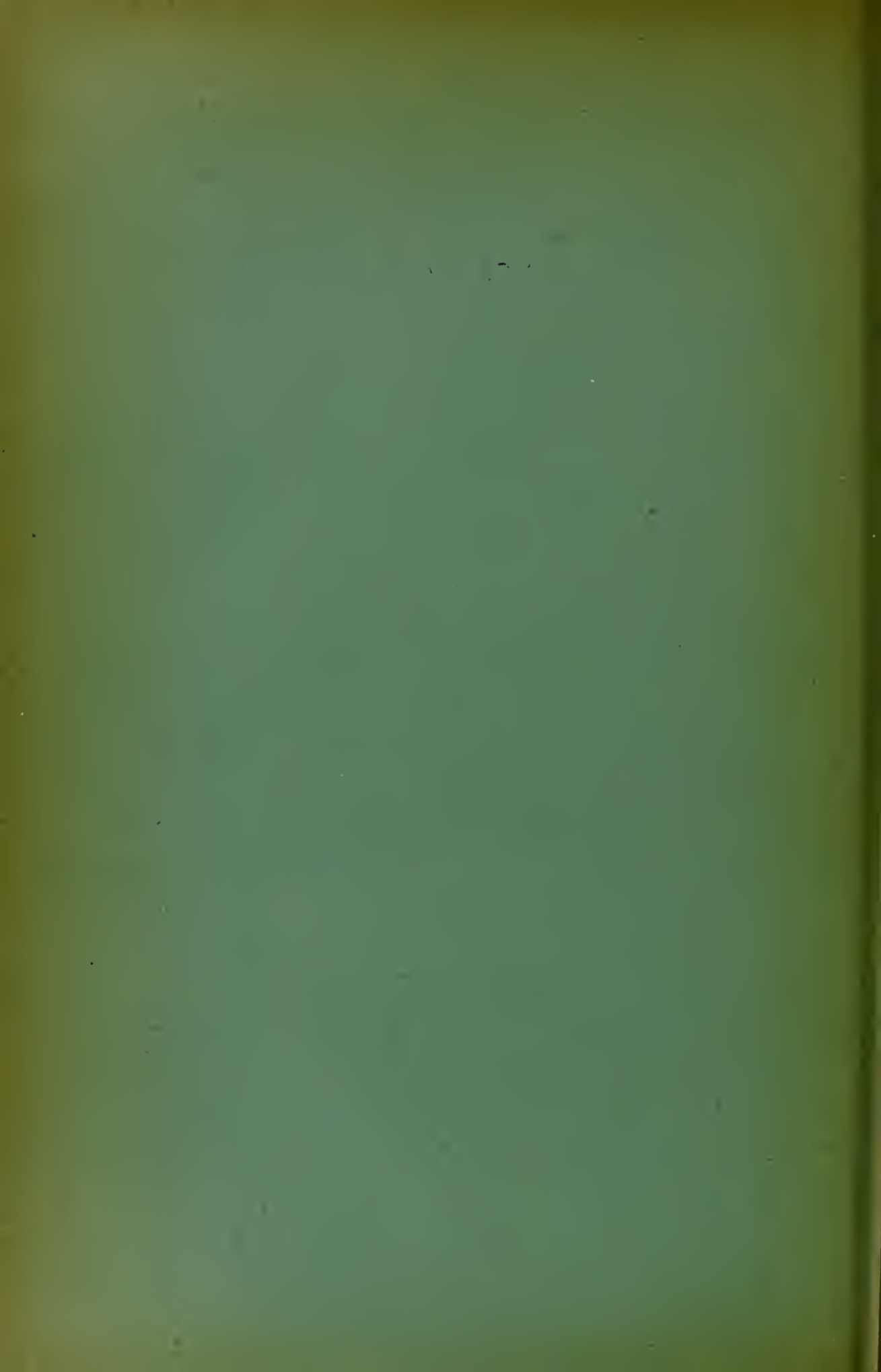
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By W. W. KEEN, M.D., LL.D., F.R.C.S.,

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CASE I. *Paralysis of the Musculo-Spiral Nerve from fracture of the humerus; displacement without apparent injury of the nerve; replacement of the nerve; slight improvement.*

R. M., æt. 6, was sent to the Jefferson Medical College Hospital, December 5th, 1894, by Dr. David Williams, of Slatington, Pa., a mining town in the interior of Pennsylvania. On May 12th, 1894, while playing, he was thrown to the ground, striking on his left elbow, and fracturing the humerus. The fracture healed with great deformity of the elbow, the axis of the fore-arm being directed inward instead of outward (Figs. 1 and 2). The displacement of the internal condyle was very marked. The fracture was probably a T-fracture. In addition to this, there was complete wrist-drop, evidently from injury to the musculo-spiral nerve. Just above the head of the radius there was a sharp thorn of bone projecting under the skin. The measurements of the arm were as follows: Olecranon to external condyle, right, 4 cm.; left, 5 cm. Olecranon to internal condyle, right, 2·8 cm.; left, 2·5 cm.

Operation, December 12th, 1894, seven months after the accident. An incision was made in the line of the musculo-spiral, and the thorn of bone was first exposed. This was found to be, as it was supposed, a displaced bony fragment. The musculo-spiral was about 2 cm. external to the spicule and was probably not injured by it. On further exposure of the bone I found that the nerve was caught by another deeper projection which acted like a hook, displacing the nerve very much to the outside and making traction upon it. The nerve did not appear to be abnormal

and hence was simply released from its bed and replaced in its normal position, the projecting portions of bone being smoothed off by the rongeur forceps. The wound was then closed as usual.



FIG. 1.

*Case I.*—The stick on the right uninjured arm in the axis of the upper arm (as nearly as may be) shows that this axis passes along the *ulnar* side of the hand. On the left (the fractured) arm the angle between the arm and the forearm is so altered that a similar stick passes beyond the *radial* side of the hand.

He made a perfectly smooth recovery, and was sent home with directions to his family physician to use electricity, massage, and passive movements persistently for at least a year unless improvement followed earlier.

His parents were unintelligent and did not appreciate the need of treatment which was kept up very irregularly for two or three months, since which time nothing has been done. Dr. Williams writes me, under date of March 19th, 1900, that "the paralysis is not quite as extensive as it was originally. My opinion is, had your treatment been kept up, the usefulness of the arm would have been restored completely. It was the fault of the parents, and the boy has to suffer for it."



FIG. 2.

*Case I.*--The figure shows the wrist-drop before operation.

CASE II. *Paralysis of the Musculo-Spiral from fracture of the left humerus ; non-union of the fracture ; resection of the false joint ; suture of the nerve ; great improvement of the function of the forearm and hand from repair of the fracture ; very little improvement in the function of the nerve.*

P. A. S., æt. 24, a student at the Jefferson Medical College. On March 31st, 1897, his left arm was caught in the belt of a machine, and he received a compound comminuted fracture of the radius, the ulna, and the humerus, with great destruction of the soft parts, especially the muscles on the posterior surface of the forearm. The fracture of the forearm united promptly, but the humerus never united. In addition to this ununited fracture, he had wrist-drop, evidently from the injury of the musculo-spiral nerve. He could flex and extend the last two phalanges of his fingers, but could not extend the first phalanges. There was also numbness over the skin of the thumb, including its metacarpal bone.

Operation, April 25th, 1898, thirteen months after the accident. An incision was made over the course of the musculo-spiral. The lower end of the nerve was found without difficulty under the supinator longus. Tracing it upward, it ended in a broad mass of connective tissue, beyond which no nerve was discovered. Following the normal groove through the external head of the triceps which was represented almost entirely by scar tissues, I finally discovered the upper end. Instead of being bulbous, the end was shrunken. The bone was laid bare a little above the junction of the middle and lower thirds, and a false joint was found. Three centimeters of the bone including the false joint were then removed. This so shortened the distance between the two ends of the nerve that they were readily brought together and sutured after freshening both ends of the nerve. This suturing was done not only to the shrivelled upper end but also to the main body of the trunk where the branch to the triceps was given off. The arm was then dressed on a bracketed iron splint with plaster-of-Paris bandages. He made an excellent recovery without incident, his highest temperature being 99.8°. The bone was somewhat slow in its repair, so that it was between



five and six weeks before I felt I could safely remove the plaster. During his convalescence he took the syrup of the hypophosphites.

He was a very intelligent patient, who co-operated with me in every way. As soon as the bone was firmly united he had electricity applied for a long time twice, and then once a day; massage, passive and, as far as possible, active movements were continued for over a year.

His present condition is as follows:—Before the operation he was unable to do any dissecting and scarcely any manipulation in the chemical and other laboratories in consequence of the want of stability of the humerus. After the operation he was able to dissect perfectly well and has pursued his medical course with great satisfaction to himself and his teachers. In May, 1900, he won the Anatomical Prize for the best dissection of the year. On November 28th, 1898, seven months after the operation, he states that on the application of electricity there was an extensor response to the cathode current and the muscles could be seen to contract under the skin. "The use I now have of my arm is a vast improvement over that of last winter."

CASE III. *Paralysis of the Musculo-Spiral Nerve from fracture of the humerus; prompt repair of the fracture; resection of the humerus in order to approximate the ends of the injured nerve five months after the accident; very speedy and entire recovery of function.*

R.C., aet. 10, was admitted to the Jefferson Medical College Hospital, March 13th, 1899, at the request of his uncle, Dr. Robert Watt, of Philadelphia. In October, 1898, he fell, fracturing the left humerus just above the elbow joint. As soon as the splint was removed wrist-drop was noticed. On admission, extension at the elbow was within  $14^{\circ}$  of the straight line. Flexion was only possible to a right angle; supination, pronation, and extension of the wrist were all gone. The last two phalanges of all the fingers of the hand were easily extended. The knuckles could not be extended; tactile sensation was only slightly impaired.

Operation, March 20th, 1899. An incision was made along

the anterior border of the supinator longus. Under the shelter of that muscle the upper end of the nerve was found without any trouble. The end of it was flattened, and attached to the callus of the fracture. No nerve tissue could be traced below this



FIG. 3.

*Case III.*—Shows the voluntary flexion of the wrist after operation.



point. The incision was prolonged over the forearm, and the radial, and the posterior interosseous nerves found. From this I was able to dissect upward, and found the lower end of the nerve readily. About 5 mm. of the lower end were removed ; at the upper end about 2 cm. were removed. The gap between the two ends was from 5 cm. By stretching it was reduced to 3·5 cm. But the two ends could not be further approximated. Accordingly the bone was laid bare, and 3·5 cm. of the humerus was resected. The ends of the bone, having been drilled before the resection, were wired together by aluminium-bronze wire. The ends of the nerve were now approximated by two fine silk stitches. The arm was put up in plaster of Paris, with a bracketed splint to give access to the wound. The highest temperature was 100·2° ; the plaster-of-Paris was removed on April 15th, 26 days after the operation. The union of the bone was perfect, with a considerable amount of callus. He was then placed in charge of his uncle, with the advice that the hot and cold douche, massage, and electricity should be applied regularly. This was begun about May 1st, at first with the galvanic current, 15 minutes at each daily sitting until the last week in July, when the muscles began to respond to the current. The faradic as well as the galvanic currents were now used, and by the second week in August he could almost extend his hand. By the beginning of September he could completely extend the hand and wrist. The usefulness of his hand, which was *perfectly* restored when I saw him on my return from my holiday in September, is best shown in the accompanying photographs. (Figs. 3 and 4.)

Prof. William G. Spiller's report on the specimen is as follows : " One of the pieces removed by Prof. Keen consists of a mass of connective tissue, with here and there structures that might be regarded as nerve fibres, but could not with certainty be asserted to be such with the carmine stain. With Weigert's hæmatoxylin stain some nerve fibres are found, but most of these stain poorly even when the tissue is only slightly decolorised. Portions of fresh tissue teased and stained with osmic acid show comparatively few nerve fibres containing myelin ; even those which are found stain very badly ; and in a number in which myelin is present, it has undergone degeneration

and appears as separate masses. In some nerve fibres these masses are large, such as have usually been observed in degenerating nerves; in others the myelin balls are very small and are like those first described by me\* in trifacial neuralgia. It is probable that the piece of nerve in which the nerve fibres are better preserved is from the upper end of the nerve."

"*Lower end.* The nerve fibres from the lower end of the nerve, teased and stained in the fresh state with osmic acid, are *intensely* degenerated. Only a small amount of myelin is found, and this exists in the form of separate balls. Not a single normal medullated fibre can be seen. The specimen is very beautiful as an example of far advanced degeneration."

\*Spiller, in paper by J. K. Mitchell, *Journal of Nervous and Mental Disease*, 1898.



FIG. 4.

*Case III.*—Shows the voluntary *extension* of the hand after operation. (Both Figs. 3 and 4 shows the lower portion of the operation scar).

CASE IV. *Fracture of the Right Humerus; Injury of the Musculo-Spiral Nerve; Suture after 13 years; no improvement.*

Clayton S., aet. 16, was admitted to the Jefferson Medical College Hospital, October 5th, 1897, at the request of Dr. Kriebel of Worcester, Pa.

When three years of age he was caught in the shaft of a grist mill, and the right arm was broken at about the middle of humerus. While the fracture was being treated, it is said that the wrist was noticed to be paralysed. It has never improved. On admission it was found that he could not extend the wrist or the fingers at the knuckle joint; the second and third phalanges could be extended. The right forearm was much shrunk; the shoulder and elbow movements were not impaired; the supinator longus was intact. All the extensors of the forearm were completely paralysed. Dr. Bochroch, of the Nervous Department, who examined him, reported that the musculo-spiral nerve failed to give any muscular contraction with either current. The extensors below the elbow showed both qualitative and quantitative changes. On examining the arm with the skiascope the outline of the humerus was so even that I almost doubted whether a fracture had ever occurred. Further investigations, however, convinced me that it had been fractured.

Operation, October 6, 1897. An incision three inches long was made at the border of the supinator longus. The lower end of the musculo-spiral nerve was readily found. On attempting to trace the nerve upward, however, all evidence of the nerve was destroyed. I, therefore, was compelled to follow up the musculo-spiral groove, dividing the internal intermuscular aponeurosis and opening the groove between the external and middle heads of the triceps muscle. I finally discovered the upper and enormously swollen end (fig. 5). The figure shows the natural size. The upper end was then removed, and also the somewhat bulbous extremity of the lower end. The gap between the two ends was then 9 cm. By stretching this could be reduced to 6 cm. The gap between the two ends was bridged by twelve strands of catgut passing through the two ends of the nerve. The arm was then placed on a splint to immobilise it in

extension. His highest temperature was  $100.2^{\circ}$ . A week after the operation the wound was entirely well, and he went home on the 16th. It was directed that he should have massage, electricity, douches, etc., for at least a year. This treatment was never properly carried out, owing to the ignorance and negligence of his parents. No improvement followed.

Prof. Wm. G. Spiller's report on the specimen (*Proceedings Pathological Society of Philadelphia*, February 15th, 1898, p. 101) is as follows :—"The much thickened proximal end was examined microscopically. In transverse sections, from the upper portion, the nerve fibres were arranged in bundles, but within the thickened epineurium many nerve fibres were found passing in all directions



FIG. 5.

*Case IV.*—Tissue removed from upper end of nerve. Natural size.

without any definite arrangement. The connective tissue of the nerve was greatly increased in amount. The longitudinal sections through the middle and lower portions of the swelling showed the nerve fibres almost without the normal arrangement in bundles. The fibres were separated from one another by connective tissue, and some ran transversely, but most had a longitudinal course. It is probable that many of these were new fibres that had grown from old axis cylinders and had become wrapt, each in a medullary sheath. They did not stain quite as intensely with the Weigert hematoxylin stain as do ordinary nerve fibres. It is hardly possible that they were merely the old fibres, which had been pushed apart by the proliferating connective tissue of the endoneurium. The swelling was, therefore, a true amputation neuro-fibroma.

"Within a short time after a nerve has been divided, several new axis cylinders grow from an older one, at some little distance above the point of division; each newly-formed axis cylinder then becomes surrounded by a medullary sheath, and constitutes a new nerve fibre. Such an amputation neuroma is in reality a neuro-fibroma, as there is proliferation of connective tissue and new formation of nerve-fibres."

CASE V. *Compound Fracture of the Right Humerus just above the Elbow; Injury of Musculo-Spiral Nerve; Suture 22 months after accident; slight improvement.*

E.C., æt. 10, was admitted to the Jefferson Hospital, October 18th, 1895, at the request of Dr. Kriebel, of Worcester, Pa.

December 7th, 1895, he fell backward out of a cart and fractured the right humerus just above the elbow. When the splint was removed after five weeks, wrist-drop was first noticed. There had been a progressive atrophy of the extensor muscles of the forearm. Supination is still present. The index and middle fingers from the distal end of the phalanges to the extremities are anæsthetic.

Operation, October 20th, 1897. An incision was made along the border of the supinator longus and the nerve readily found. I first searched upward and downward without finding any solution of continuity. At the level of the old compound fracture, however, the nerve was thickened; it was not bound down by any adhesions or callus. The thickened portion of the nerve (2.5 c.m.) was removed, and the two ends sutured together after stretching them. The resection was just below the origin of the branch to the supinator longus. He made a very excellent operative recovery, and was returned to Dr. Kriebel's care with the request that the same treatment should be carried out as in the other cases. On December 3rd, 1898, Dr. Kriebel reported "some improvement in extension." As in the former case his parents were very ignorant and negligent in carrying out my directions.

Prof. Wm. G. Spiller (*Proceedings Pathological Society of Philadelphia*, February 15th, 1898, p. 100) describes the changes in the nerve as follows:—"The nerve fibres were found in a far



better state of preservation than could have been expected, in view of the extensive paralysis which had lasted for nearly two years. In two or three nerve bundles, very decided changes were noted; in these the medullary sheaths were much less numerous than in normal nerves, and, therefore, the hæmatoxylin of Weigert did not stain these fasciculi deeply, and the carmine stain showed some swelling of the axis cylinders. The epineurium, perineurium, and endoneurium were not notably thickened. The moderate swelling of certain axis cylinders indicated that the process was progressive, for this swelling of the axis cylinder is an early stage of degeneration. Far more than half of the fibres appeared to be normal. It is evident, therefore, that complete paralysis may be the result of injury of a comparatively small number of fibres within a nerve, and this fact is one of considerable importance."

CASE VI. *Division of Musculo-spiral by a knife blade; Suture three months after its division; good functional results.*

(This case has already been published in full in the *Therapeutic Gazette*, Detroit, Michigan, U.S.A., July 15th, 1895, by Dr. Wharton Sinkler. I include it to make my series complete.)

A résumé of the case is as follows:—

F. C., male, æt. 26, in the early part of February, 1894, was stabbed in the left arm with a penknife. The wound was a scant centimeter in length. There was no numbness nor loss of power noticed in the hand that night. The day following he found that the extensors of the wrist and fingers were paralysed and that there was a sensation of pins and needles in the thumb and forefinger. The wound healed in a few days. Dr. Sinkler first saw him April 25th, 1894. He confirmed the existence of wrist-drop. Tactile sensation was preserved over the entire hand, with the exception of an area on the posterior and inner aspect of the thumb, extending from the carpo-metacarpal articulation to the last phalangeal joint. In this region the sensation was lessened, but not lost. The muscles were very much wasted. Marked reaction of degeneration was present.

Operation, May 15th, 1894, by Dr. Keen. The nerve was markedly bulbous at the point where it had been wounded



(Fig. 6). This bulbous portion was excised, and the two extremities were stretched sufficiently to bring the ends in contact. They were then sutured with two silk threads.



FIG. 6.

*Case VI.*—Shows the bulbous swelling of the nerve at the point of its division.

Dr. D. Braden Kyle examined the specimen, and reported as follows —

“The microscopical appearance of the longitudinal section showed the following: Above and below the bulbous portion, the tissue presented much the normal appearance, except its reaction to stain, the cells seeming to be swollen or undergoing some infiltrating process, the nerve sheath being thickened. In the bulbous portion partial longitudinal sections of nerve filaments could be demonstrated, but the main part of the bulbous portion was composed of fibrous connective tissue. Whether this was inflammatory product, or whether it was an attempt at the re-establishment of the nerve by regeneration, I cannot say. I think that it was possibly more a hyperplasia of the neuroglia than anything else, and that there were distinct nerve-fibres present; these fibres were widely disseminated, and were not arranged in bundles, the nerve tissue reacting to stain very much the same as that beyond the bulbous portion. I cannot say that there was any particular bulging on either end of the injured

nerve. Transverse sections of the nerve fully confirm the appearance of the longitudinal. As to the exact character of the nerve element present, it is very difficult to say. My own belief is that, first of all, there has been over-development of the fibrous nerve-sheath within which is slowly developing the nerve-fibres, and that should this process continue, function would largely be re-established."

Electrical treatment was begun May 26th, and continued with fair regularity. In September, massage was begun. In the latter part of October, Dr. Sinkler found that the patient began to have slight power to extend the wrist.

On December 26th, Dr. Sinkler found the following conditions:—"The patient is able to extend the wrist fully and strongly; there is also full power of extension of all the fingers. He uses his hand for all ordinary purposes, driving frequently a pair of hard-pulling horses. The sensation is fully restored over the area in which it was impaired. With the dynamometer the grip of the right hand is 140; left, 65. The extensor muscles of the left forearm still fail to respond to the faradic current, either with slow or rapid interruption. There is an improvement, however, in the reaction to the galvanic current. There is still marked quantitative changes, but the reaction of degeneration is no longer present. The anodal closing contraction is about equal to the cathodal closing contraction."

"On April 9th, 1895, fourteen months after the division of the nerve and eleven months after nerve suture, an examination of the patient shows decided gain in muscular power since the last note. The patient can extend the hand and fingers strongly, and says that he feels no sense of weakness in using it. With the dynamometer the right hand registers 130; the left, 84. None of the muscles supplied by the musculo-spiral nerve respond to the faradic current. The reaction of degeneration is no longer present; in fact, there is but slight reaction to the galvanic current with either anodal or cathodal closure. A very strong current causes slight tetanic contraction of the extensor carpi radialis. Sensation in the hand is normal, as is the temperature of the part."

## REMARKS.

The musculo-spiral nerve is peculiarly exposed to accident. Like any other nerve, it may be divided by a stab-wound, gunshot-wound, etc., but there is, perhaps, no other nerve in the body so frequently injured in the fracture of an adjacent bone as is the musculo-spiral in fractures at and below the middle of the humerus.

From the unfortunate character of the result also, the accident merits attention, for, when a complete wrist-drop exists, the hand is practically made useless. If, in addition to this, as in Case II. an ununited fracture of the humerus occurs, the uselessness of the hand becomes practically absolute. The result of a secondary neurorrhaphy is frequently not very good. This is due, I think, to several causes: First, as in several of my cases, from the ignorance and carelessness of the parents, little or no after treatment is carried out, and unless persistent massage, douching, and electrical treatment is systematically carried out for at least a year, and it may be longer, we can scarcely expect any good result. The simple suture of the nerve, leaving the muscles wasted from their long non-use, will of itself do but little good. The result in Cases III. and VI., especially the former, was so good that surgeons may well take heart in such cases.

The methods which I adopted in the cases here related were simple suture after stretching; secondly, stretching and bridging the still existing gap in the nerve with strands of catgut, and deliberate resection of the shaft of the humerus in two cases. If the stretching alone brings the freshened ends into apposition, nothing more, of course, need be done. In cases in which the two ends cannot be brought into approximation, some means of bridging the gap must be employed. The two cases in this series in which I used catgut resulted in no improvement. I feel this was due partly to the carelessness of the parents in carrying out the after-treatment, but how far it was due to the want of value of the method, one cannot say. I am inclined to blame the method quite as much as the imperfect after-treatment. In Case III. the result was certainly not only perfect, but much more speedy than I had expected.

Who was the first to suggest a deliberate resection of the humerus, I do not know, but I am inclined to think that the

credit belongs to my fellow townsman, Dr. Oscar H. Allis. In the *Medical News* for July 25th, 1891, will be found a paper, entitled "Problems in Surgery," The fifth problem is that of an injury of the musculo-spiral. In this case he states that in three instances he has advised resection of the humerus, but he was not permitted to carry out the plan. In Tillman's Text Book of Surgery, Vol. I., Regional Surgery (American Edition, 1898, p. 607), it is stated "In case of extensive defects, Löbker suggested shortening the bones of the forearm by resecting a piece of piece of bone from their continuity" in order to bring the ends of the nerve together. I have not had the time to ransack surgical literature in order to determine the relative claims of Löbker and Allis. Rose and Carless ("Manual of Surgery," p. 349) mention having resected the humerus for an injury of the musculo-spiral. Of course, whether the resection is done in one bone or another is a matter of indifference. The principle is the same. The result in this case was so excellent that I most heartily commend it to surgeons. In Case II. in which the same expedient was resorted to, not only to approximate of the nerve ends, but on account of ununited fracture, a good result could hardly be expected, because the muscles of the forearm were so extensively lacerated and repaired by cicatricial tissue, as seriously to interfere with their function. The restoration of the humerus to its normal solidity, however, made a useless into a useful hand.

In connection with Case II., the young man with ununited fracture of the humerus, one other point is of importance. The operation was done in April, 1898. The bone was wired with aluminium-bronze wire. One year afterwards the wire was still present and showed no signs of disintegration. Two years afterwards, examination by the X-rays shows that the wire has entirely disappeared. A material which will remain in the tissues innocuously for probably fifteen or eighteen months and will then disappear entirely is certainly of great value, especially in the surgery of the bones.

My colleague, Prof. J. Chalmers DaCosta, has also used fine aluminium-bronze wire as a buried suture in cases of hernia. Unfortunately his cases were patients in the Philadelphia Hospital, which is the city almshouse, and in only one of them is the result known at any considerable time after the operation. About a year afterwards the wire was still in place without causing the slightest annoyance.